

## *Diphasiastrum multispicatum* (J.H. Wilce) Holub (Lycopodiaceae) in Thailand

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ABSTRACT.—Review of a herbarium specimen (QBG) and subsequent field studies have revealed that *Diphasiastrum multispicatum* occurs near the summit of the two highest mountains in Thailand. This species is restricted to SE Asia and grows exclusively at higher elevations in the submontane to montane zone. Previously, it has been reported from China, the Philippines, Taiwan, and Vietnam, but not from Thailand. A comparison of the plants from Thailand with those from the type locality of *D. multispicatum* in the Philippines (Mt. Santo Thomas near Baguio City, Province of Benguet, Luzon), where this species is still present, shows the plants from Thailand to be *D. multispicatum*. Like other *Diphasiastrum* species, *D. multispicatum* is a weak competitor and grows on (disturbed) immature soils on slopes with more or less open and low growing vegetation. We also present morphological evidence that *Diphasiastrum multispicatum* is distinct from *Diphasiastrum complanatum* s.s., which is a north temperate, circumboreal species (in northern and central Europe, Greenland, northern North America, Japan and northern Asia, excluding the tropics).

The genus *Diphasiastrum* comprises a relatively small group of lycopods that differ morphologically from the genus *Lycopodium* s.s. in several traits, such as leaves (mostly) 4–5-ranked (and not spirally arranged), leaves (mostly) di- or even trimorphic (and not isomorphic), and upright shoots (mostly) quadrate to flattened (and not rounded). This group was formerly treated as section *Complanata* of genus *Lycopodium* (Wilce, 1965; Øllgaard, 1987, 1989, 1990), but Holub (1975a) proposed it as a separate genus *Diphasiastrum*, and this treatment has been accepted in many modern floras (e.g., Dostál, 1984; Wagner and Beitel, 1993; Jermy, 1993; Kukkonen, 2000). The genus includes about 25 species of mainly north temperate and subarctic distribution. Only a limited number of species occur in the tropics or subtropics, where they are restricted to mountainous areas. Species with a southeast Asian distribution include *Diphasiastrum angustiramosum* (Alderw.) Holub, *D. multispicatum* (Wilce) Holub, *D. platyrhizoma* (Wilce) Holub, *D. veitchii* (Christ) Holub, and *D. wightianum* (Wall. ex Hook. & Grev.) Holub (Wilce, 1961, 1965). Additionally, taxa of unresolved relationship occur in this area and were called the “Chinese plant” and the “New Guinea plant” in the monograph by Wilce (1965). The “Chinese plant” might be conspecific with the plants described as *D. yueshanense* C. M. Kuo and *D. wilceae* Ivanenko (Kuo, 1985; Ivanenko, 2003). To our knowledge, no recent comparative studies are available for these critical taxa.



In the last century, *Diphasiastrum* was still unknown in Thailand (Tagawa and Iwatsuki, 1979). Later, a single species was reported under the name *Lycopodium complanatum* L. (Boonkerd and Pollawatn, 2000). However, *Diphasiastrum* (= *Lycopodium*) *complanatum* is a north temperate, circum-boreal species which occurs in northern and central Europe, Greenland, northern North America and extending to Japan and northern Asia. Wilce (1965, p. 103) states explicitly: "There is no true *L. complanatum* either in the tropics (even on mountain slopes), or in the southern hemisphere". We present evidence that *Diphasiastrum multispicatum* (Wilce) Holub occurs in Northern Thailand, where it occupies the peaks of the two highest mountains.

#### MATERIALS AND METHODS

Pteridophytes in the herbarium of Queen Sirikit Botanic Garden (Mae Rim, Chiang Mai, Thailand; QBG) were studied by two of the authors (W.B. and P.S.) in September 2005 and in February 2006. Field collection of plant specimens on Doi Inthanon were made in the same months (by W.B. and P.S.) and on Doi Pha Hom Pok (by P.S.) in October 2005. Additionally, *Diphasiastrum* specimens kept in the herbaria of Berlin (B) and Aarhus (AAU) were annotated by K.H. The type locality of *Diphasiastrum multispicatum* on Mt. Santo Thomas (Luzon, Philippines) was revisited in November 2005 (by P.S.) and February 2006 (by W.B.). A Global Positioning System (GPS) instrument (Garmin GPS 72) was used to determine altitude and coordinates of the Philippine and Doi Inthanon populations; for Doi Pha Hom Pok, these data were obtained from a topographical map. SEM images of spores were made using a scanning electron microscope (DSM 950, Zeiss).

#### RESULTS AND DISCUSSION

*Morphology.*—A herbarium specimen that was labeled as "*Lycopodium complanatum*" (collected on the peak of the highest mountain in Thailand, Doi Inthanon, *Nanakorn s.n.* QBG no. 6601) was discovered while studying pteridophytes in the herbarium of Queen Sirikit Botanic Garden (Mae Rim, Chiang Mai, Thailand; QBG). The plant is clearly different in its morphology from *Diphasiastrum complanatum* (= *Lycopodium complanatum* L.; the type specimen of this species is unknown (see Wilce 1995, p. 143 ff. and Holub 1975b)) and was identified as *Diphasiastrum multispicatum*. The site and the population on Doi Inthanon were subsequently studied on several field trips. Later, another population was discovered on the second highest mountain in Thailand, Doi Pha Hom Pok (by P.S.). Plants from the type locality on Mt. Santo Thomas (Luzon, Philippines) were studied for comparison.

Table 1 summarizes diagnostic characters that distinguish *D. complanatum* from *D. multispicatum*. The latter is the more robust species, which becomes evident especially from the dimensions of the rhizomes and peduncles. Its most distinguishing characters are the long branchlets with a very glaucous lower side and strongly incurving lateral leaves, moderately well-developed



TABLE 1. Morphological comparison of *Diphasiastrum complanatum* and *Diphasiastrum multispicatum* (mainly after Wilce, 1961 & 1965).

Characters	<i>Diphasiastrum complanatum</i>	<i>Diphasiastrum multispicatum</i>
<b>Characters being different</b>		
rhizome	terete, 1.7 (1.1–2.7) mm in diameter	terete to somewhat flattened, 2.2 (1.3–3.2) mm broad and 1.7 (1.3–2.3) mm thick
color of lower side	pale, lighter in color than upper surface, but not glaucous	strongly glaucous
ventral leaves (free blades)	1.3 (0.7–2.1) mm	1.8 (1.2–2.5) mm
lateral leaves (including bases)	5.0 (2.6–7.3) mm	4.6 (3.2–6.2) mm
dorsal leaves (including bases)	4.8 (2.8–7.0) mm	3.8 (2.8–5.2) mm
diameter of peduncles	0.6 (0.4–0.9) mm	1.0 (0.8–1.1) mm
number of strobili	strobili few, 3–4, occasionally 5 or 6 per peduncle	strobili numerous, generally 8 or more, though occasionally as few as 4 per peduncle
<b>Characters in common</b>		
	lateral branchlets of upright shoots distinctly flattened, leaves of ultimate branchlets 4-ranked, scale-like, trimorphic, ventral leaves of branchlet less conspicuous than dorsal ones, strobili pedunculate	

lower leaves with evident decurrent leaf bases (Fig. 1), a sharply defined transition between fertile branch and peduncle, and the number of strobili per peduncle being significantly greater than in *D. complanatum* (Wilce, 1961, 1965). Not surprisingly, the two species share a number of traits that are typical for the genus *Diphasiastrum*, like lateral branchlets of upright shoots flattened, leaves of ultimate branchlets 4-ranked, scale-like and trimorphic (Table 1).

Fig. 2 shows photographs of the habitat, part of the population and morphological details of the plants. Number of strobili per peduncle and the bright, almost silvery lower surface are good field characters to identify the plants as *Diphasiastrum multispicatum*. At the type locality on Mt. Santo Thomas (near Baguio City, Province of Benguet, Luzon, Philippines), the occurrence of *Diphasiastrum multispicatum* was confirmed, and 4 populations were found at different altitudes (Table 2). The growth habit and the morphology of these plants completely agree with the Thai plants (Fig. 2).

Another difference was found for the spore micromorphology (Fig. 3). In all Lycopodiaceae the spores are trilete and subglobose to subtriangular in outline (Tryon and Lugardon, 1991). Those of *Lycopodium s.l.* show a very characteristic structure composed of reticulate elements or baculae arranged in a honey-combed like pattern. Wilce (1972) recognized 4 types of such reticulate spores with the most common *clavatum* type being present in section *Lycopodium* (*Lycopodium s.s.*) and section *Complanata* (*Diphasiastrum*). While the reticulum is always continuous on the distal face, it may be broken, reduced, or lacking on the proximal face (Wilce, 1972; Tryon and



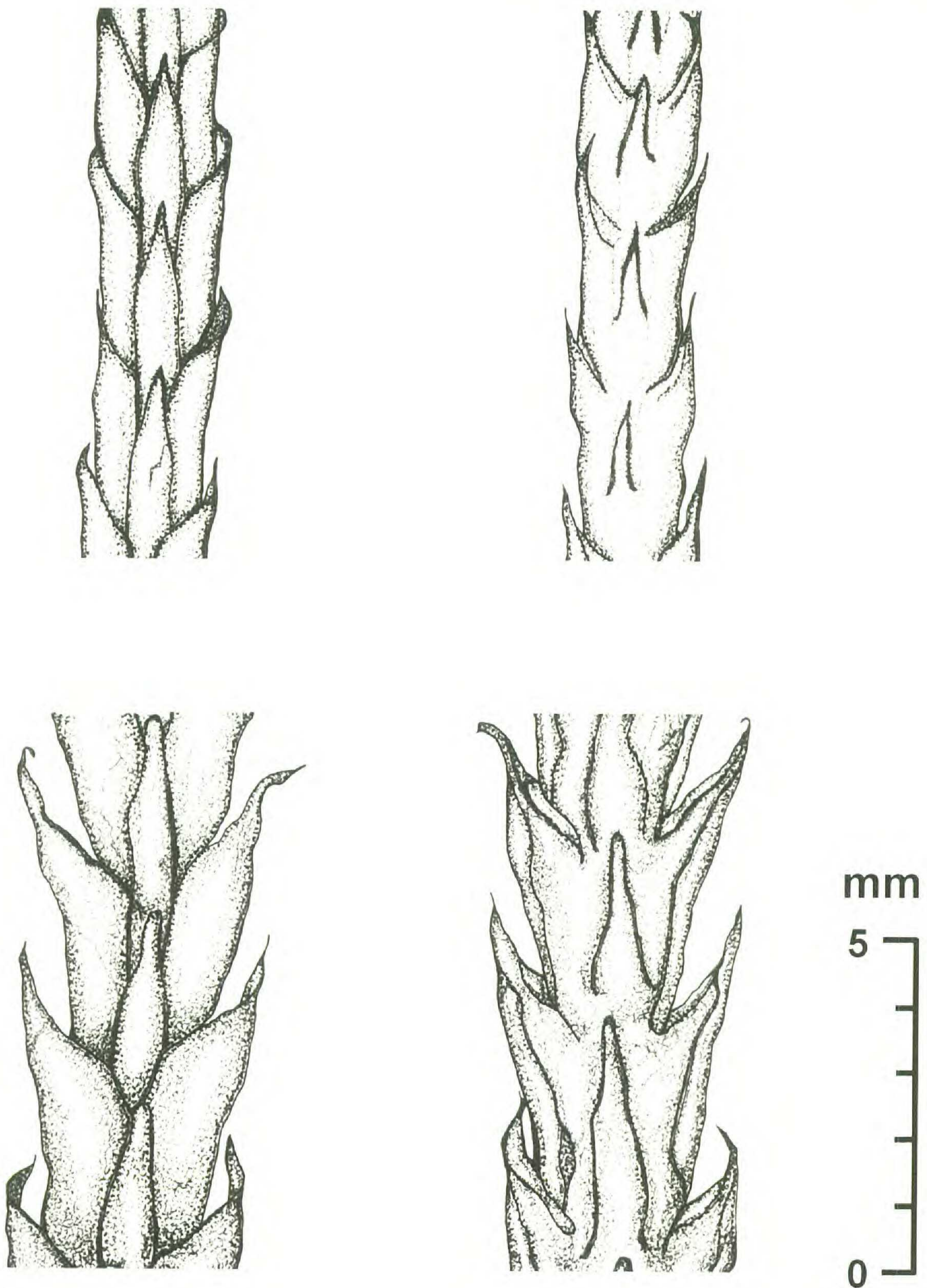


FIG. 1. Line drawing of *Diphasiastrum complanatum* (above) and *D. multispicatum* (below) showing branchlets in dorsal (left) and ventral view (right).

Lugardon, 1991). In *Diphasiastrum multispicatum*, the outer one-third of the proximal face is reticulate, but the meshwork is gradually reduced towards the aperture and is lacking between the triradiate arms. This is in contrast to *D. complanatum* and other European *Diphasiastrum* species, where the re-



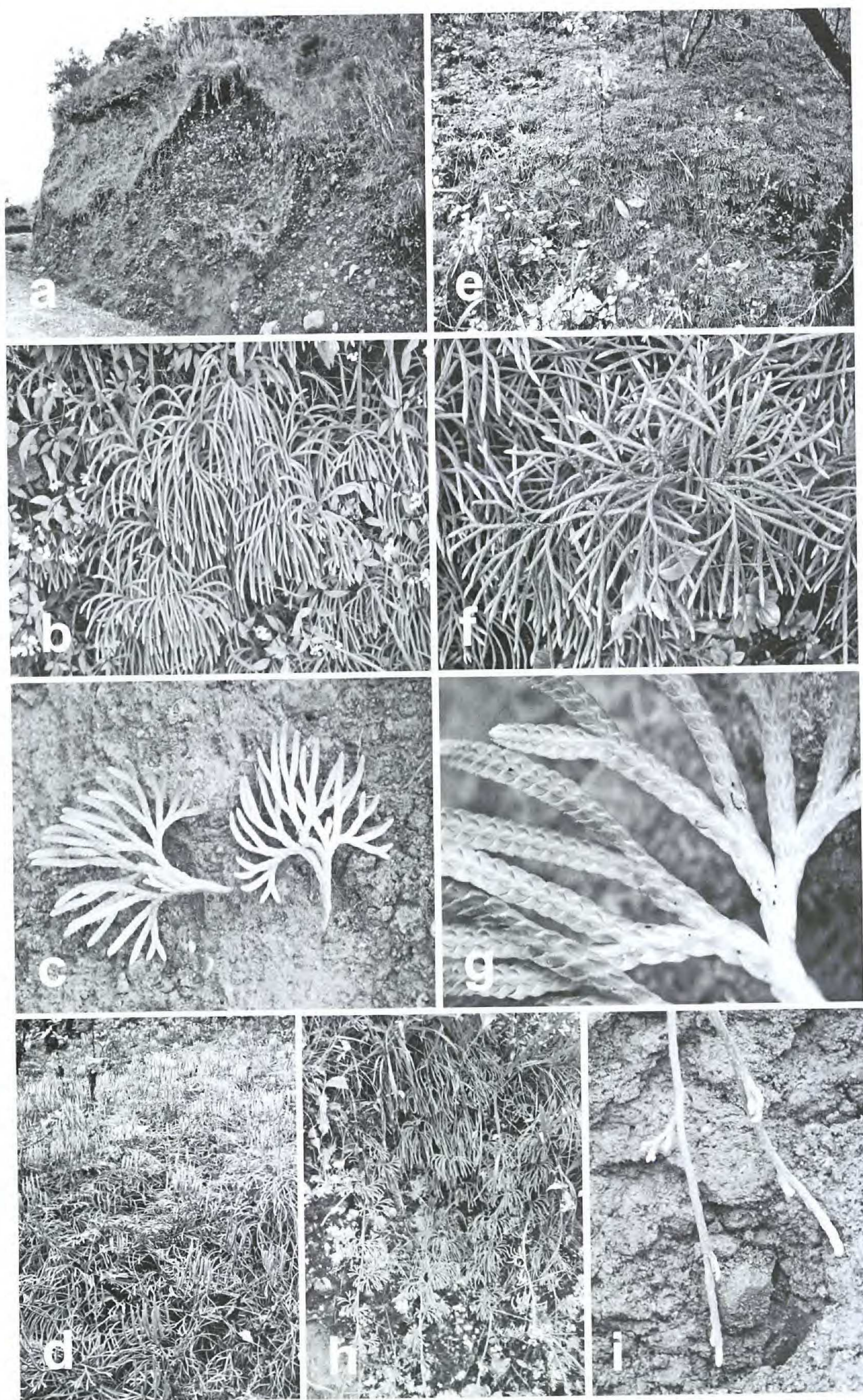


FIG. 2. *Diphasiastrum multispicatum* in the Philippines (a–d, h–i) on Mt. Santo Thomas (Luzon, type locality), and in Thailand on Doi Inthanon (e–g); open habitats along roadside (a, e), growth form of upright shoots (b, f), lower side of branches (c, g), part of colony with strobili (d), rhizome growth over blank soil on steep roadside slope (h–i).



TABLE 2. Geographical position of the two *Diphasiastrum multispicatum* localities in Thailand and of the type locality in the Philippines.

Country	Altitude (m asl)	Coordinates
<b>Thailand</b>		
Doi Inthanon	2,243	N 18° 33.754' E 98° 29.046'
Doi Pha Hom Pok	1,950	N 20° 06' E 99° 07'
<b>Philippines</b>		
Mt. Santo Thomas		
population 1	2,260	N 16° 20.115' E 120° 33.651'
population 2	2,215	N 16° 20.203' E 120° 33.592'
population 3	2,196	N 16° 20.204' E 120° 33.585'
population 4	2,003	N 16° 20.546' E 120° 33.444'

ticulum is well-developed also on the proximal face and extends to the base of the raised arms of the aperture (Fig. 3; see also Ferrarini *et al.*, 1986). Another distinguishing feature of *D. multispicatum* is the frequent occurrence of perforations in the walls of the reticulum, visible on both faces (Fig. 2i–j).

*Diphasiastrum* is remarkable in North America and Europe for its ability to form homoploid, apparently fertile interspecific hybrids (Flora of North America, 1993; Stoor *et al.*, 1996), which are morphologically intermediate between the putative parents. Kuo (1985) describes *Lycopodium yueshanense* (= *Diphasiastrum yueshanense*) as a new endemic species from Taiwan and reports that it is intermediate between *L. veitchii* (= *D. veitchii*) and *L. multispicatum* (= *D. multispicatum*) both morphologically and ecologically. Thus, *D. yueshanense* may well represent the first example of a homoploid hybrid in the tropics.

*Ecology and Distribution.*—*Diphasiastrum multispicatum* is a weak competitor and colonizes (disturbed) immature soils on slope cuttings that have been created by man with more or less open and low growing vegetation. All checked sites in Thailand and in the Philippines are located on steep road cuts (Fig. 2). In most cases, two other lycopods, *Lycopodium clavatum* L. and *Lycopodiella cernua* (L.) Pic. Serm., were observed in the vicinity.

In other continents *Diphasiastrum* species often grow on secondary sites as well, both in the tropics and in the temperate zones. *Diphasiastrum thyoides* (Willd.) Holub from South and Central America, for example, is reported from way- and roadsides, clearings, scrub and fallow land (Øllgaard, 1988, 1995). Also *D. fawcettii* (F. Lloyd & L. Underw.) Holub from Jamaica and Hispaniola is known to occur on clearings, sunny embankments and open slopes with scattered shrubs (Proctor, 1985). In most parts of their North American and Central European range, the *Diphasiastrum* species display a preference for younger secondary habitats on immature soils with an only fragmentary plant cover. Examples are roadsides, slopes of forest roads, other cuttings, ski runs and their margins, abandoned pits, firebreaks along railways, forest aisles, clearings under power lines and younger afforestations (e.g., Ardelmann *et al.*, 1995; Horn, 1997; Bennert, 1999).



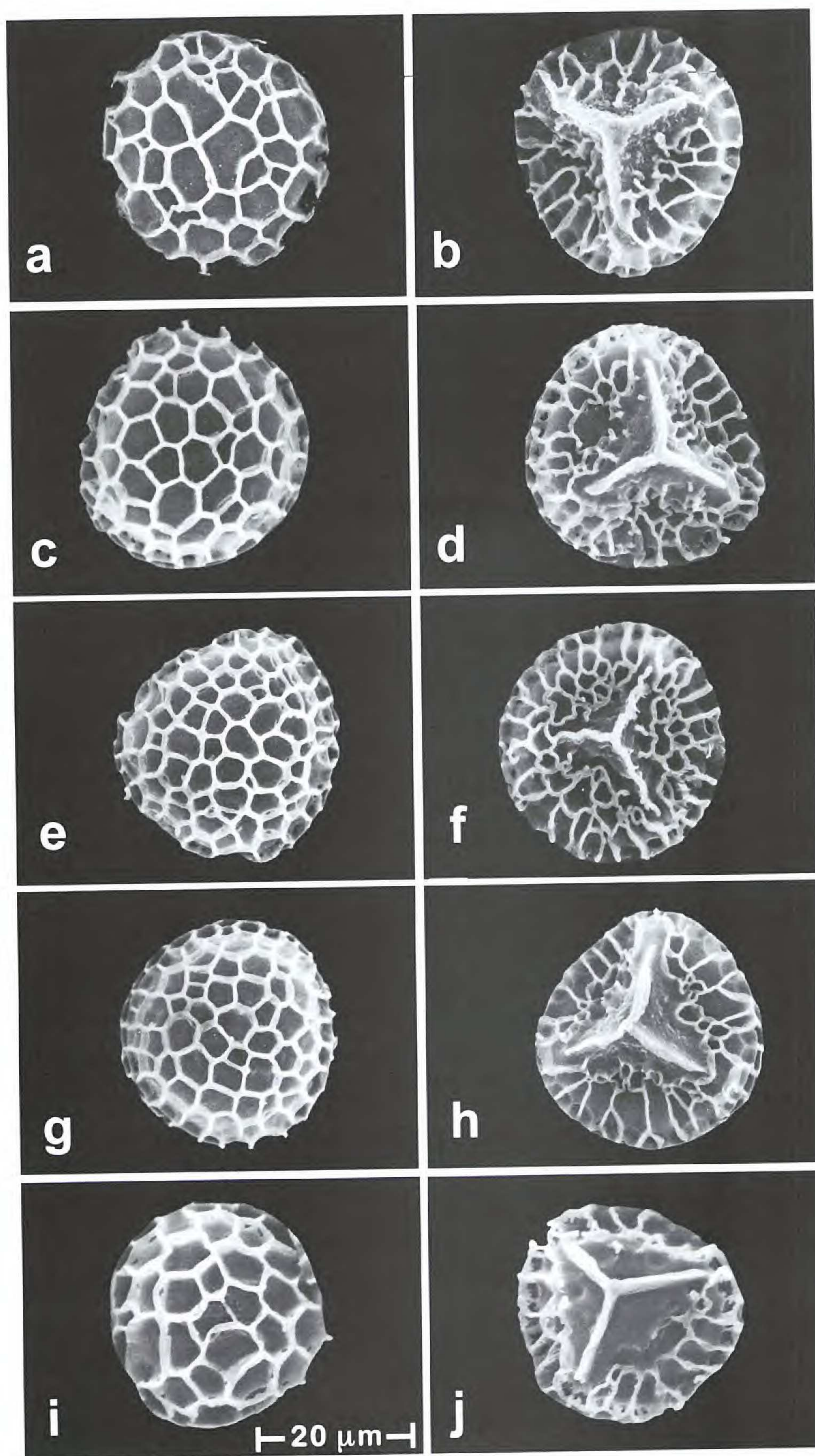


FIG. 3. SEM photographs of spores of *Diphasiastrum multispicatum* (Thailand, Doi Inthanon) and European *Diphasiastrum* species (a-h) showing distal (left column) and proximal face (right column); a-b: *D. alpinum*, c-d: *D. complanatum*, e-f: *D. issleri*, g-h: *D. zeilleri*, i-j: *D. multispicatum*.



The altitudinal range of *Diphasiastrum multispicatum* observed was 2,003–2,260 m on Mt. Santo Thomas in the Philippines, and in Thailand 1,950–2,243 m on Doi Inthanon and Doi Pha Hom Pok (Table 2); thus *Diphasiastrum multispicatum* represents a montane species in both countries.

Doi Inthanon National Park, approximately 80 km south of Chiang Mai, encompasses the highest mountain in Thailand, Doi (Mt.) Inthanon, as well as several lesser summits. The park covers an area of 48,240 ha. Its lowland areas (< 800 m) are covered by a dry dipterocarp forest which gives rise to an evergreen forest (above 1,000 m), where annual rainfall exceeds 2,500 mm. The slopes around the summit area (2,300–2,565 m) carry a moist hill evergreen forest ('cloud forest') with many epiphytes. The temperature may drop to  $-8^{\circ}\text{C}$  and frosts are not unusual during the dry season. Doi Pha Hom Pok lies approximately 80 kilometers north of Chiang Mai is the second highest mountain in Thailand (2,285 m). Vegetation types are almost the same as on Doi Inthanon.

Mt. Santo Thomas lies above Baguio City (approximately 250 kilometers north of Manila) in the heart of the Province of Benguet. Baguio City itself is situated at an elevation of about 1,400–1,500 m and has an average annual temperature of  $18.2^{\circ}\text{C}$  and an annual precipitation of 4,179 mm (recording period 17 years; see: [www.globalbioclimatics.org](http://www.globalbioclimatics.org) - climate diagram of Baguio City). If we assume the temperature to drop by ca.  $0.5^{\circ}\text{C}$  when the elevation increases by 100 m, an average annual temperature of about  $14^{\circ}\text{C}$  would result for the peak area of Mt. Santo Thomas. Annual precipitation is expected to be somewhat higher than in the city. The presently known area of distribution in Thailand comprises only two sites, and few additional localities are to be expected, as there are a limited number of higher mountains with an elevation exceeding 2,000 m. Other countries in SE Asia from which *Diphasiastrum multispicatum* has been reported are China (southern part), the Philippines, Taiwan, and Vietnam. In the recent treatment of *Lycopodiaceae* in the Flora of China (Xianchun and Libing, 2004), *Diphasiastrum multispicatum* is not recognized as a separate species, but united with *Diphasiastrum complanatum*. The latter has been split into two varieties, the typical var. *complanatum* and var. *glaucum*. From the short diagnosis given by Ching (1982) in his description of var. *glaucum* and from the appearance of the type specimen (a photo of which was supplied by Y. Ivanenko), we conclude that this variety refers to *Diphasiastrum multispicatum*. This already has been proposed by Ivanenko (2003). The total altitudinal distribution in these countries ranges from 1,165 m to 2,415 m corresponding to the submontane to montane zones (Wilce, 1961, 1965). Table 3 summarizes the recorded localities. Thus, the discovery of *Diphasiastrum multispicatum* in Thailand is a remarkable range extension, and the mountains in northern Thailand harbor the westernmost known populations of this species. *Diphasiastrum multispicatum* is likely to occur in the neighboring country of Laos as well, where several sufficiently high mountains are located with the tallest mountain, Phou Bia in the Annamese Cordillera, attaining 2,817 m above sea level.



TABLE 3. Records for *Diphasiastrum multispicatum*; data compiled from literature and obtained from herbarium revision (indicated by B [Botanischer Garten und Botanisches Museum Berlin-Dahlem, Germany] or AAU [University of Aarhus, Denmark]). The distribution given in the Chinese literature refers to *Diphasiastrum complanatum* var. *glaucum* which is a synonym of *Diphasiastrum multispicatum*.

State	Region/province/district	Locality	Reference
<b>China</b>	Prov. Guangxi		Xianchun & Libing, 2004
	Prov. Yunnan		
	Prov. Xizang (Tibet)		
	Eastern Yunnan	Pingbian Xian	Ching, 1982
<b>Taiwan</b>	Distr. Ilan	Taipingshan	DeVol & Kuo, 1979
	Distr. Hsinchu	Tapachienshan	DeVol & Kuo, 1979
	Distr. Nantou	Kuantaochi	DeVol & Kuo, 1979
	Distr. Chiayi	Mt. Alishan	DeVol & Kuo, 1979
			M.T. Kao (7486), 13.12.1968, det. C.M. Kuo as <i>L. complanatum</i> , rev. K. Horn (2003), AAU
	Distr. Kaohsiung	Kuanshanakou	DeVol & Kuo, 1979
	Distr. Hualien	Mukuashan	DeVol & Kuo, 1979
		Mt. Taiheizan	Wilce, 1961
	Arisan	Wilce, 1961	
<b>Thailand</b>	Prov. Chiang Mai	Doi Inthanon	this paper
	Prov. Chiang Mai	Doi Pha Hom Pok	this paper
<b>North Vietnam</b>	Prov. Bac Phan (Tonkin)	Nam-kep, Massif du Pia-Quac	Wilce, 1961
		Chapu, Lo Qui Ho between Cao-Bang and Nguyen-Binh	Wilce, 1961
		Col de Lo Qui Ho, pres Chapa: Cha-pa et Cho-bo	E. Poilane (12641), 13.5.1927, as <i>L. complanatum</i> , rev. K. Horn (2003), ex P, AAU
<b>South Vietnam</b>	Prov. Kontum	no exact locality given	Averyanov <i>et al.</i> (VH 183), 17.3.1995, as <i>L. complanatum</i> , rev. K. Horn (2003), AAU
<b>Philippines</b>	Luzon, Prov. Benguet	Mt. Tabiao	Hb. E.B. Copeland, 25.10.1905, as <i>L. complanatum</i> var. <i>thyoides</i> , rev. K. Horn (2005), B
	Luzon, Prov. Benguet	Mt. Santo Thomas; Baguio	Wilce; 1961, 1965
	Luzon, Prov. Nueva Viscaya (?)	Mt. Tonglon	Wilce; 1961, 1965
	Luzon, Prov. Laguna	Mt. Maquiling; Mt. Banahao	Wilce; 1961, 1965



## ACKNOWLEDGMENTS

We thank Mrs. Ilse Wessel, Bochum, for preparing the drawings of *D. complanatum* and *D. multispicatum*, and Mr. Marcus Streckenbach, Bochum, for providing the SEM photos of the spores of *D. multispicatum*. Also, thanks are due to Prof. Dr. Brigitte Zimmer, Berlin, and Prof. Dr. Benjamin Øllgaard, Aarhus, for sending herbarium specimens on loan (from the herbaria B and AAU). Dr. Yury Ivanenko, St. Petersburg (Russia), sent us a photograph of the type specimen of *D. complanatum* var. *glaucum* kept in PE (Institute of Botany, Chinese Academy of Sciences, Beijing), and Prof. Dr. Zhixiang Zhang, Beijing (China) contributed information on the occurrence of *D. multispicatum* in China; both are gratefully acknowledged. Jeff Stauffer, Wrightwood (CA, USA) and Dr. Nicola Bennert, Riverside (CA, USA) contributed to improving our English.

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